HXS Off-Line Tests at LLE

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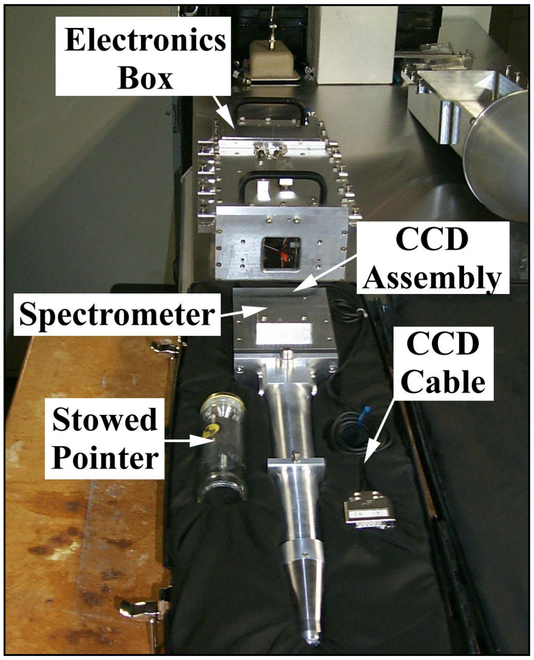
Summary

The Hard X-Ray Spectrometer (HXS) was assembled and tested off-line in La Cave. The spectrometer, drive electronics, and battery module were deployed in TIM2. After a technical problem with the trigger fiber optic cable was solved, x-ray spectral CCD images were recorded on a number of target shots on a ride-along basis. The HXS drive electronics were perturbed on some shots. After lead shielding was added to the front end of the drive electronics box, triggering and CCD image acquisition were normal, and all instrument functions were successfully demonstrated. The instrument's control computer was connected to the LLE Ethernet. These tests were facilitated by Jack Armstrong, Greg Pien, and many other LLE technical personnel.

Contents

1. Benchtop Assembly in La Cave

On Monday, November 13, the instrument was unpacked and laid out on a bench in La Cave as shown in Fig. 1. The attachment of the pointer to the nosecone was demonstrated. As shown in Fig. 2, the CCD cable was connected to the Drive Electronics (DE). The spectrometer was bolted to the DE box. The battery cable and the data and trigger fiber optics were connected. The cooling fluid lines were fit checked.



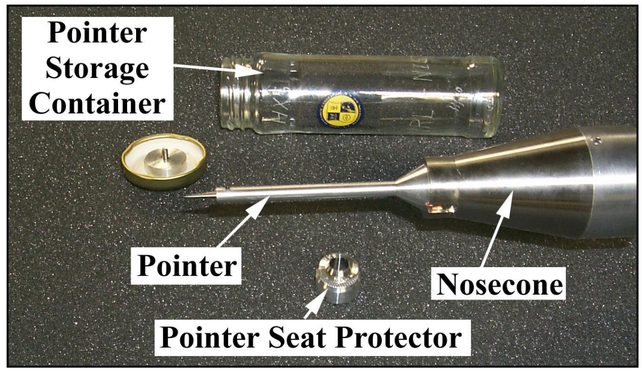
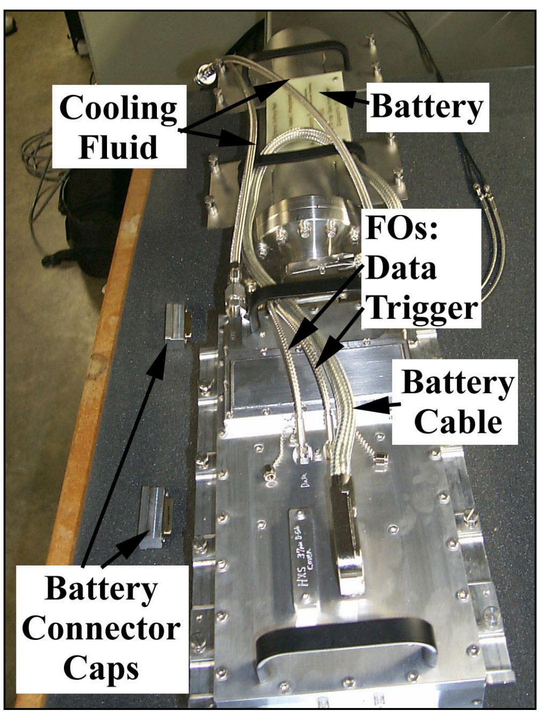


Fig. 1. The benchtop layout of the instrument in La Cave.



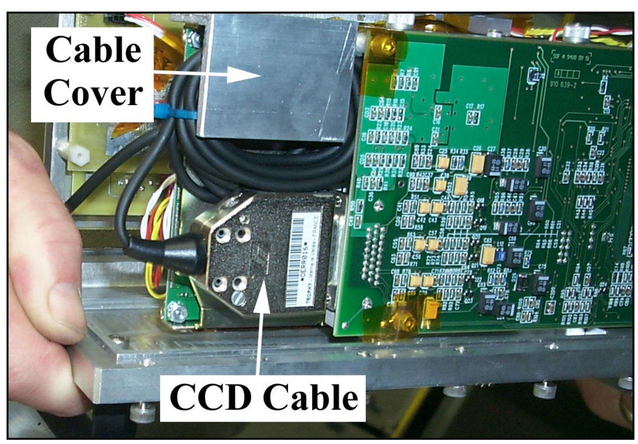


Fig. 2. The connection of the cabling.

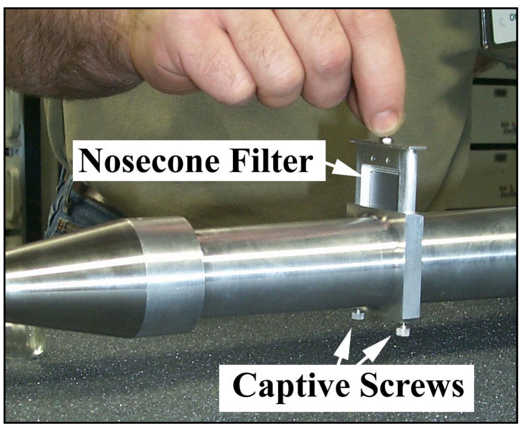
2. Filters

As shown in Fig. 3, the nosecone filter frame is removed by loosening the two captive screws on the bottom of the nosecone assembly. A 5.4 mil thick beryllium filter was mounted on the frame.

A 1 mm titanium filter was mounted on one position of the pinhole filter support. The other position was open. Thus one of three different pinhole filter settings could be chosen: (1) Open, (2) 1 mm Ti filter, or (3) Closed.

As shown in Fig. 3, the attenuation filter (or crossover slit filter) frame is removed by loosening the two captive screws on the top of the frame. Cadmium and yttrium filters were mounted as shown in Fig. 4. This filter arrangement provided on the CCD three open (unfiltered) regions, 1 and 2 mil cadmium filtered regions, and a 4 mil yttrium filter region. Two additional attenuation (crossover slit) filter frames are provided with the instrument.

The transmittances of these and other filters are shown on the next page. A black plastic filter covered the CCD detector.



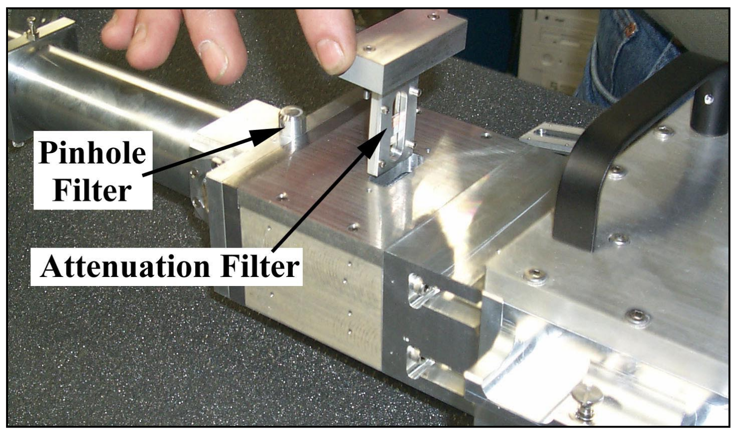
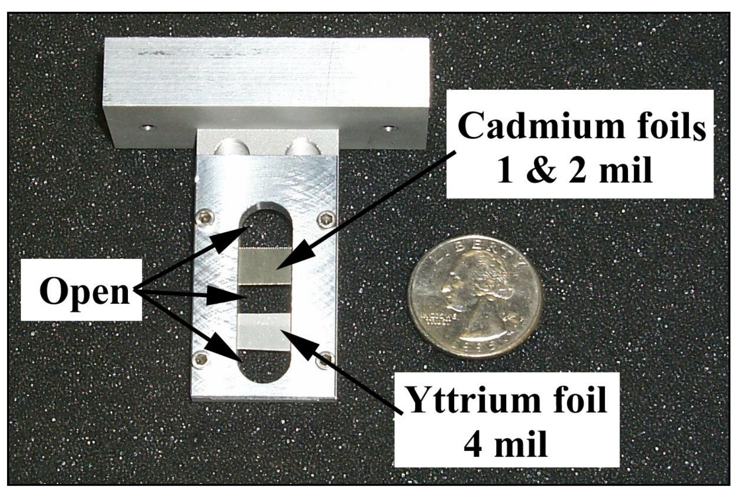
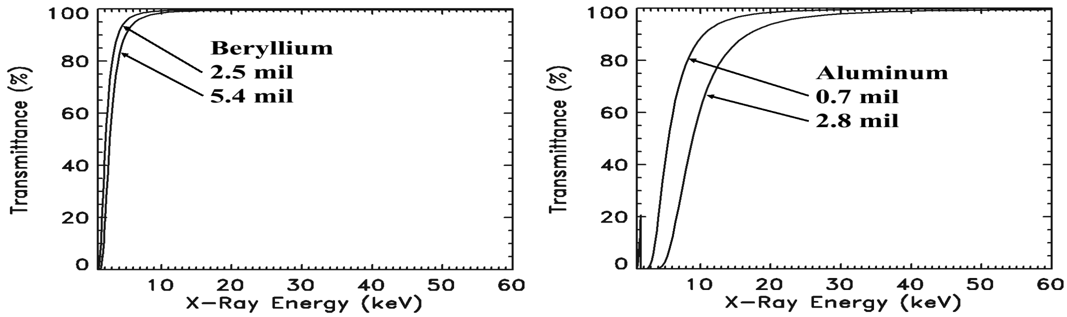


Fig. 3. The nosecone, pinhole, and attenuation filters

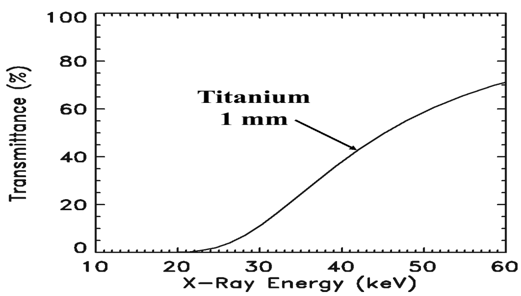
Fig. 4. The attenuation filters.



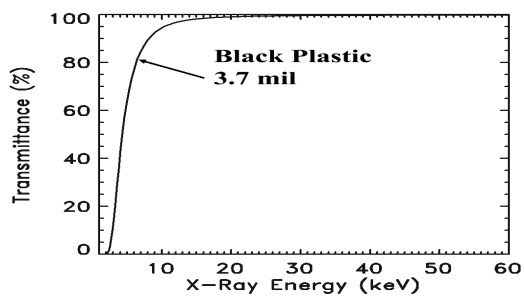
Nosecone Filters



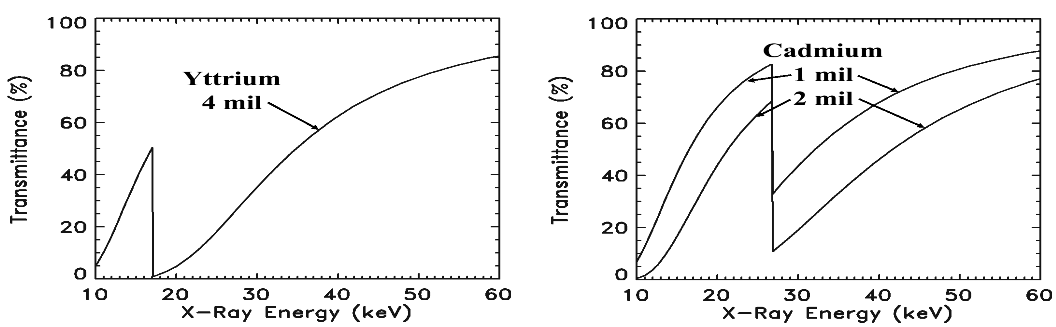
Pinhole Filter



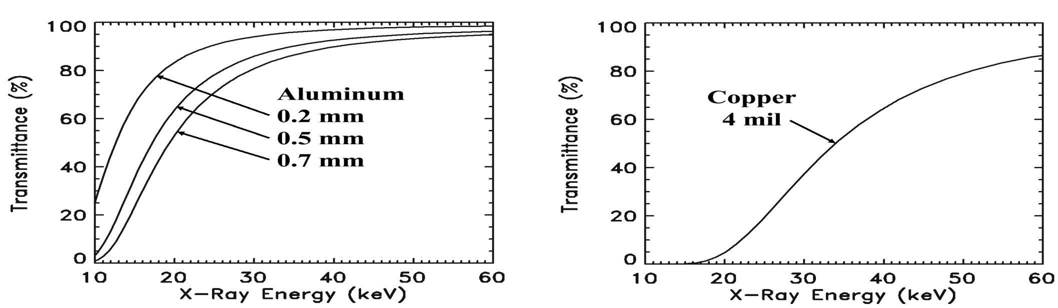
CCD Filter



Crossover Slit K Edge Filters



Crossover Slit Attenuation Filters



3. Diagnostic Control Processor (DCP) and Diagnostic Interface Unit (DIU)

The DCP, DIU, and FO Patch Box were positioned on a shelf in La Cave as shown in Fig. 5. The instrument's Data and Trigger FO cables and the LLE Trigger cable were connected to the back of the DIU.

Communications with the instrument were tested in La Cave. The forced trigger from the DCP/DIU was acquired by the instrument, and a CCD image was downloaded.

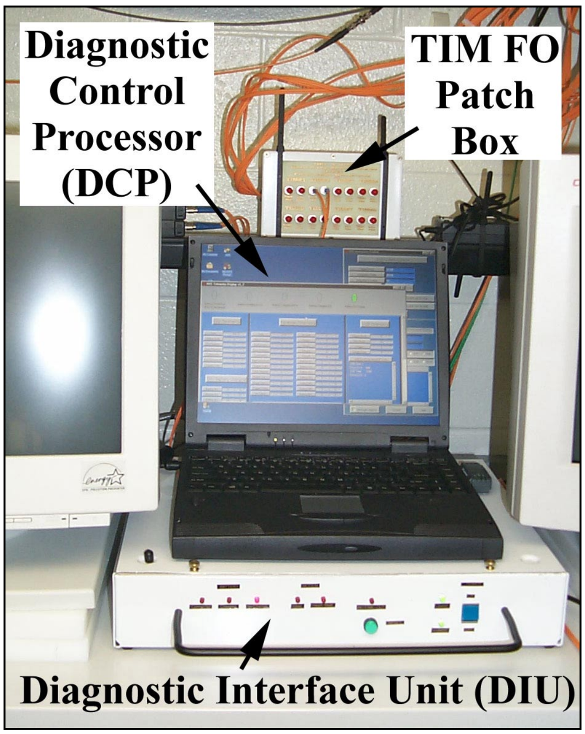
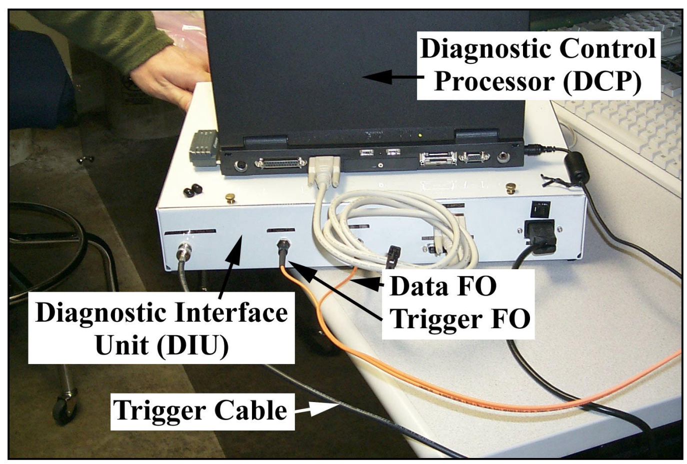


Fig. 5. The arrangement of the DCP, DIU, and FO Patch Box and the cable connections.



4. Deployment in TIM2

On Monday afternoon, November 13, the instrument was deployed in TIM2 as shown in Fig. 6 with the assistance of a number of LLE technical personnel. The Data and Trigger FO cables and the cooling cables were connected. Communication between the DCP/DIU in La Cave and the instrument in TIM2 was verified. The pointer was attached to the nosecone, and TIM2 was evacuated. The instrument was deployed into the target chamber, and the pointer was positioned at TCC. The DE was powered up, and the temperature sensors were in the normal range. The instrument was retracted, and the pointer was removed in preparation for the shots on the following day.

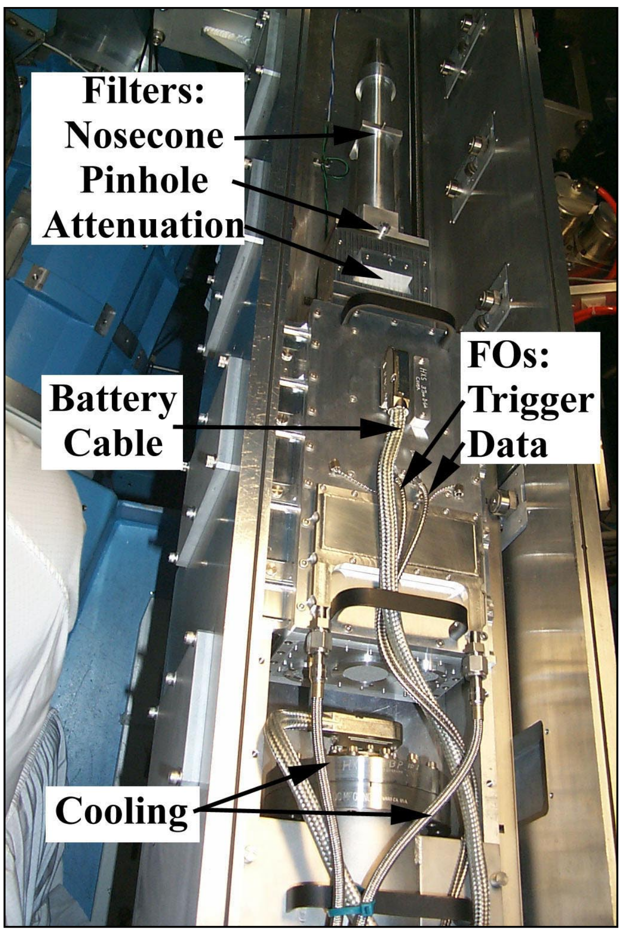


Fig. 6. The deployment of the instrument in TIM2.

5. CCD X-Ray Spectral Image Acquisition on Ride-Along OMEGA Shots

The forced trigger from the DCP/DIU in La Cave to the instrument in TIM2 was tested Tuesday morning and found to be inoperable. The cause was determined to be 75% optical intensity losses, primarily at the TIM2 FO vacuum feedthrough and the FO in the TIM2 umbilical. The feedthrough and FO in TIM2 were replaced , and the trigger was functional. Owing to time constraints, the instrument was not deployed into the target chamber. However, the instrument was properly triggered on shot #8, and an unexposed (dark) CCD image was downloaded.

The instrument was deployed into the target chamber for shot #9, and an excellent x-ray spectral image was acquired as shown in Fig. 7. The target type was D_2(3)CH[24]. The laser conditions were: 60 beams, 23 kJ, 1 ns square pulse, SSD on. The instrument filters were as follows: 5.4 mil Be nosecone filter, open (unfiltered) pinhole, and at the crossover slit 1 and 2 mil Cd and 4 mil Y as discussed above. In addition, the black plastic filter covered the entire CCD surface.

The open and filtered regions of the CCD image are indicated in Fig. 7. The yttrium K absorption edge at 17.038 keV is clearly visible in the image. The x-ray flux was not sufficiently high to see the cadmium K absorption edge at 26.716 keV.

The spectra, summed vertically over the various open and filtered regions of the image, are plotted in Fig. 8(Top) with an energy scale previously determined during tests at NIST. The spike-like features in Fig. 8(Top) result from bright pixels. As shown in Fig. 9, the locations of the bright pixels are not correlated in the three CCD images that are shown. The bright CCD pixels may result from the deposition of energy by gamma rays or energetic particles. The bright pixels may be removed by applying a 2D lowpass digital filter to the CCD image. The result is shown in Fig. 8(Bottom).

The pinhole image in Fig. 7 is centered at pixel position (column,row) = (900,698). The tests at NIST indicated a pinhole image position of (907,669) when the x-ray source was centered on the axis of the spectrometer. Mispointing of the spectrometer in the vertical direction shifts the spectral image in the vertical direction on the CCD with a minimal effect on the throughput. However, mispointing in the horizontal direction alters the range of angles on the cylindrically bent crystal and does affect the throughput. The NIST tests indicated a horizontal FOV of ±3 mm which corresponds to ±34 pixels. Thus the 7 pixel horizontal shift in the pinhole image is within the FOV. The observed pixel shifts indicate that the pointing of the spectrometer axis at LLE differed from that at NIST by 0.6 mm in the horizontal direction and 2.5 mm in the vertical (unimportant) direction.

Since the pinhole image was quite dark on shot #9 (see Fig. 7), it was decided to implement the 1 mm Ti pinhole filter for the next shot. Thus the 1 mm Ti pinhole filter would attenuate the pinhole image without altering the filtration of the dispersed spectral image. The 1 mm Ti pinhole filter was implemented by retracting the instrument, venting TIM2, rotating the pinhole filter support to the 1 mm Ti filter position, pumping TIM2, and re-deploying the instrument for shot #10.

An x-ray CCD image was acquired on shot #10, and downloading was initiated. Although the instrument's battery was inadvertently disconnected before the entire image was downloaded, the portion of the downloaded image looked normal. The battery was brought to La Cave for overnight re-charging.

On Wednesday morning, November 15, a 5 mil copper filter strip was added to the center crossover slit filter frame to provide additional attenuation of the pinhole image. Thus the pinhole image would be attenuated by 5 mil copper and 1 mm titanium. The yttrium filter was changed to a 4, 8, and 12 mil step wedge. The 1 and 2 mil cadmium filters were unchanged. The instrument was re-deployed in the target chamber.

On the first laser shot, the instrument functioned properly, but the integration time was inadvertently set to T-1.5 to T-0.5 rather than T-0.5 to T+0.5. The resulting CCD image, unexposed to the plasma produced by the laser pulse, looked normal. The DE latched during the second shot on a 1 mm gold uniformity target. The instrument's power was cycled from the DCP/DUI in La Cave. On the third shot, the DE triggered properly but the USB interface to the CCD did not integrate. The instrument was removed from TIM2 and brought to La Cave. Three power removal and image acquisition cycles were successfully performed. The DE appeared to have suffered a Single Event Upset (SEU) on the previous shot and had latched up. Power removal for the 10 minute period while the instrument was brought to La Cave apparently cleared the condition. As shown in Fig. 10, 1/2" lead shielding was added to the front end of the DE box. X-ray spectral CCD images were acquired on Thursday, November 16, without DE malfunction.

For all shots on Thursday, the crossover slit filter was the same as the previous day. No spectrua were observed on the three gold pointing and uniformity shots. Spectra and pinhole images were observed on all of the subsequent D_2/CH target shots. Thus the absence of spectra from the gold pointing and uniformity shots was attributed to the very weak hard x-ray emission from these types of targets.

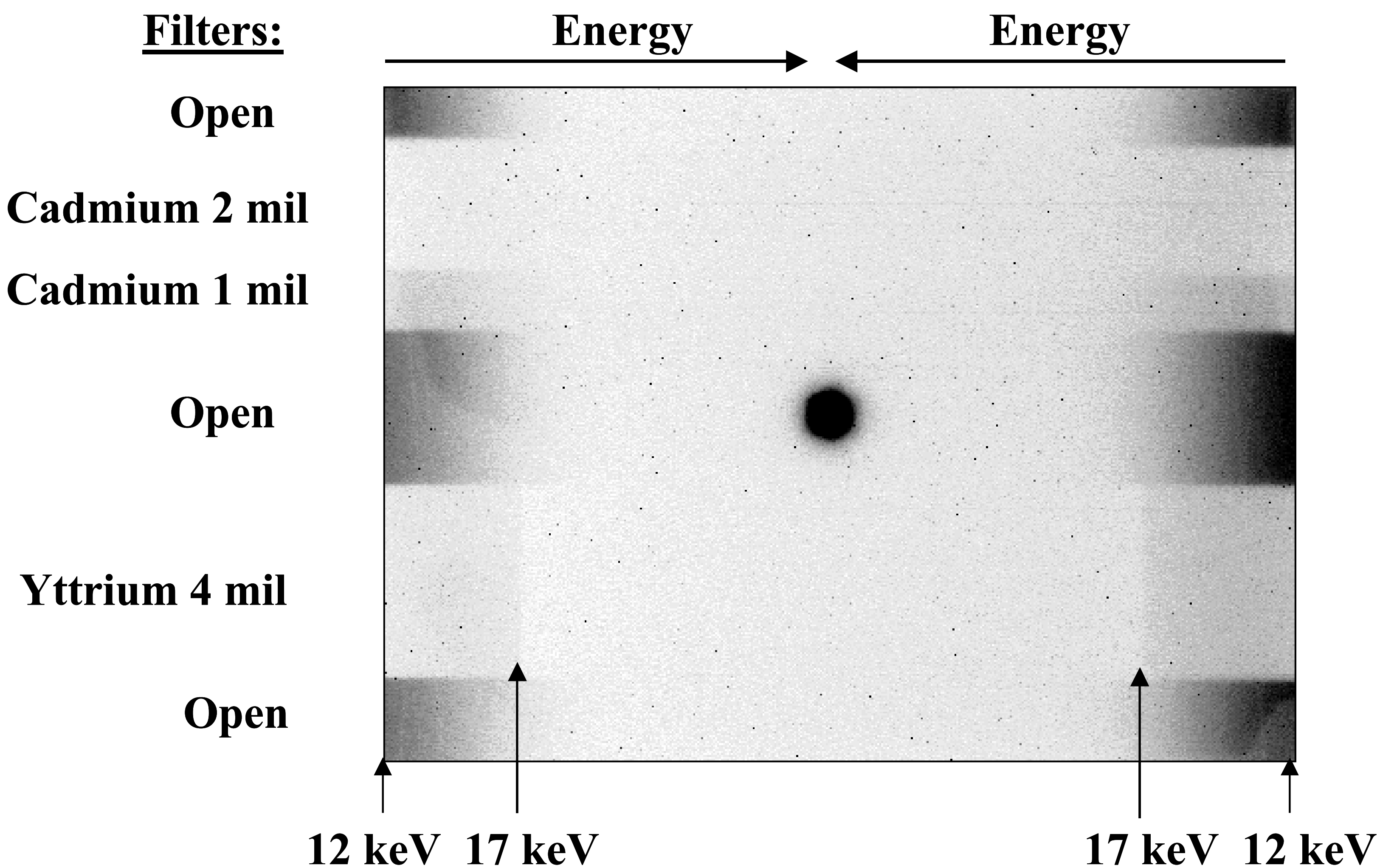


Fig. 7. The x-ray spectral CCD image from shot #9 on Tuesday, November 14.

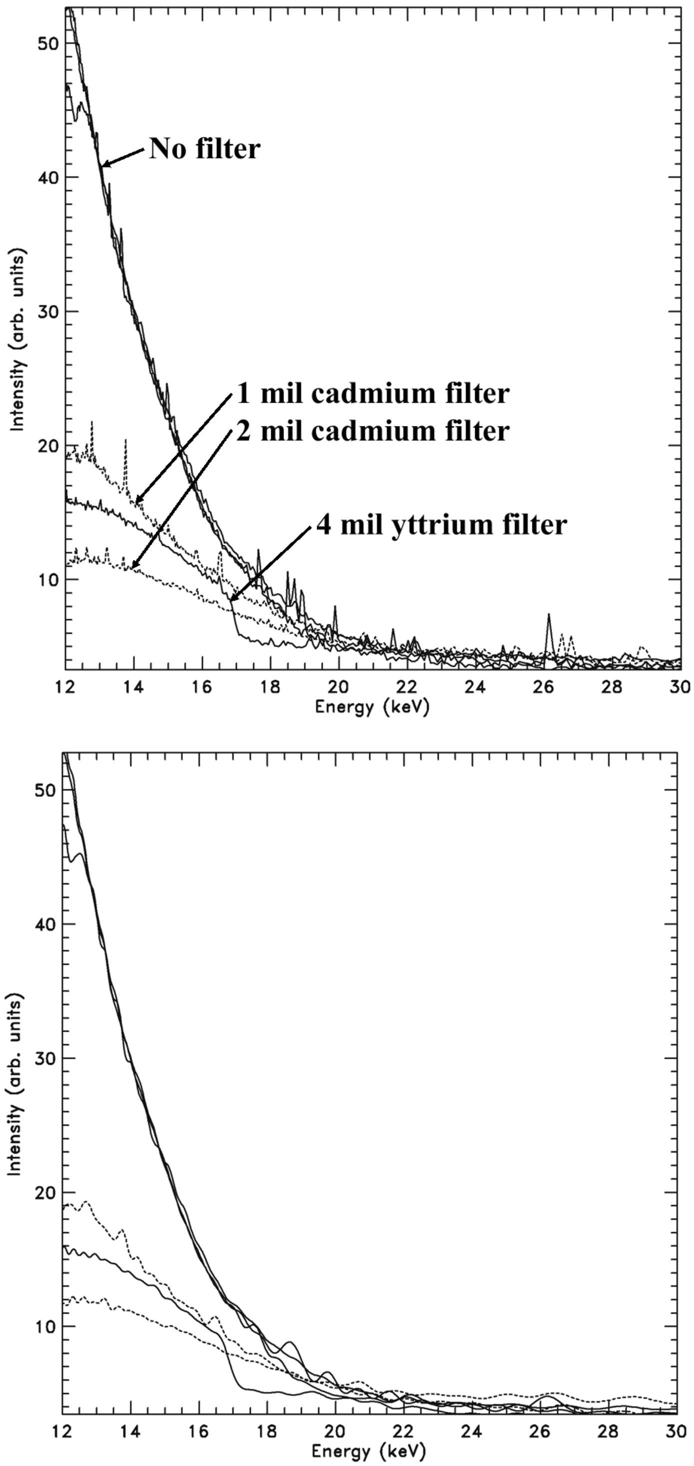


Fig. 8. Top: The spectra in the open and filtered regions of the CCD image shown in Fig. 7. Bottom: The spectra after 2D lowpass Fourier processing of the CCD image.

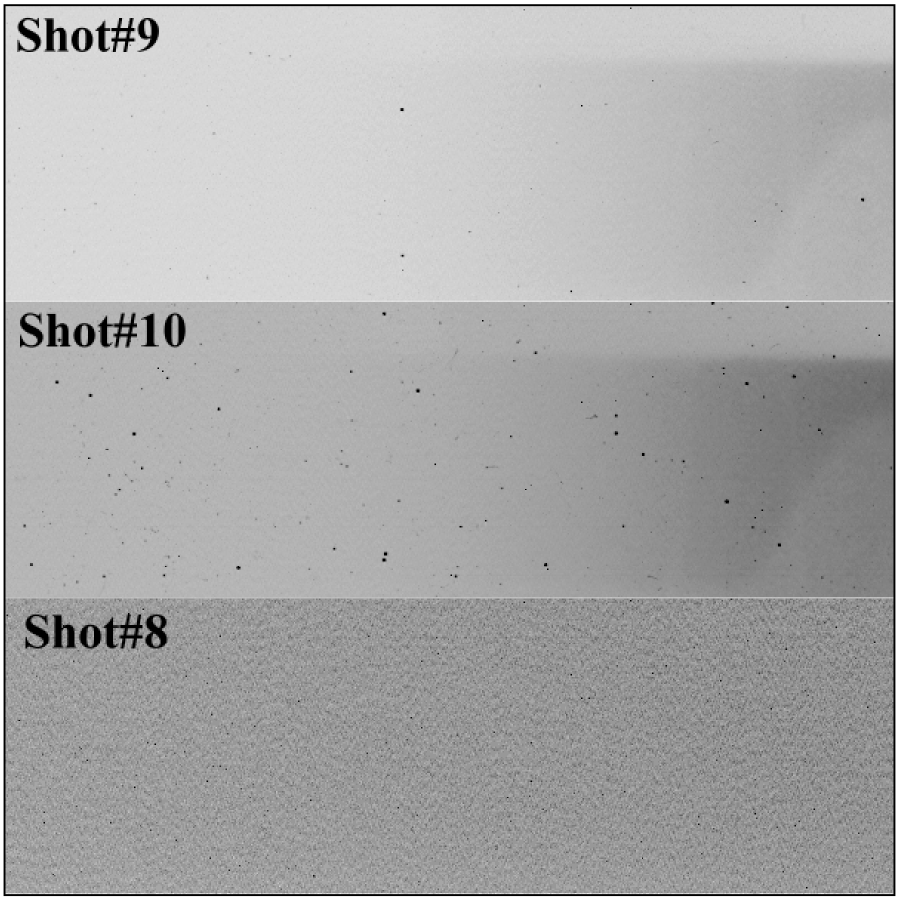
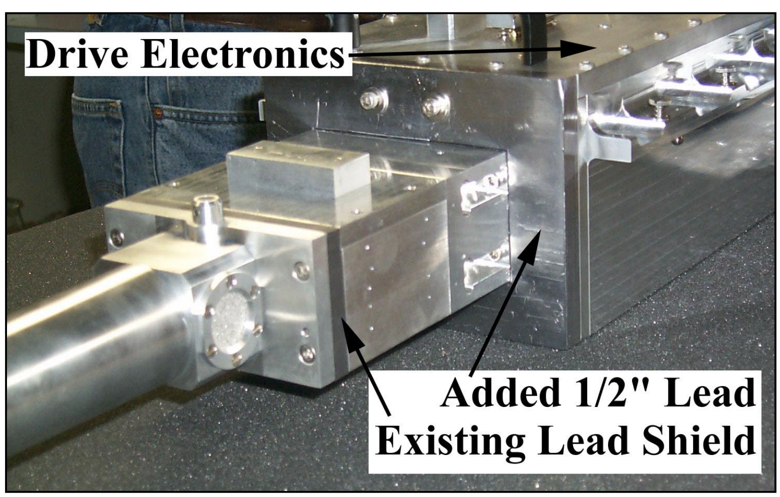


Fig. 9. Comparison of bright pixels from three shots on Tuesday, November 14.

Fig. 10. Lead shielding added to the front of the DE box.



6. Connection to the LLE Ethernet

On Thursday, November 16, the DCP was connected to the LLE Ethernet as shown in Fig. 11. After making software modifications, the LLE OIP command sequence was implemented, and good CCD images were acquired in an automated manner.

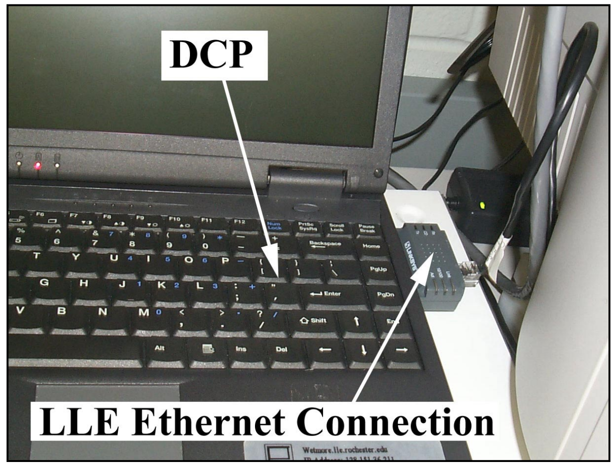


Fig. 11. The LLE Ethernet connection to the DCP in La Cave.